MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

DET5038 – POWER ELECTRONICS

(Diploma in Electronics Engineering)

24 OCTOBER 2019
9.00 AM –11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This question paper consists of 7 pages excluding the cover page.
2. Answer ALL questions. All necessary working steps must be shown.
3. Write all your answers in the answer booklet provided.

QUESTION 1 [20 marks]

(a) An ideal electronic controllable switch has four major ideal characteristics which enable the switch to work perfectly. Briefly explain each of the four ideal characteristics of an electronic switch.

(10 marks)

(b) A rectifier is used to convert AC input voltage to DC output voltage. One of the types used is a single phase half wave rectifier with a pure resistive load.

(i) Draw the circuit diagram for a single phase half wave rectifier with a pure resistive load.

(2 marks)

(ii) Explain the operation based on the positive half cycle and negative half cycle of the circuit.

(4 marks)

(iii) Draw the input voltage Vs(t) and output voltage $V_R(t)$ waveforms with time.

(4 marks)

Continued ...

QUESTION 2 [20 marks]

(a) State the type of DC-DC converter and draw the circuit based on the characteristic of the input voltage and output voltage stated below:

(i) Input voltage is 12V and output voltage is 100V.

(3 marks)

(ii) Input voltage is 100V and output voltage is 12V or 200V.

(3 marks)

(iii) Input voltage is 100V and output voltage is 12V.

(3 marks)

(b) Draw the output load current waveform of a single phase half wave bridge inverter if the load is a:

(i) Resistor

(2 marks)

(ii) Inductor

(2 marks)

(iii) Resistor in series with an inductor

(2 marks)

(c) State the four drawbacks of switch-mode operation and the type of circuit used to overcome these drawbacks.

(5 marks)

Continued ...

QUESTION 3 [20 marks]

A power MOSFET with the following circuit and parameters is used as a switch to energize a resistive load.

Drain-source on state resistance, $R_{DS\text{-}on} = 0.02\ \Omega$

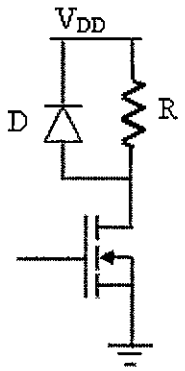
On state current, $I_{D\text{-}on} = 20$ A

DC power supply, $V_{DD} = 100$ V

Turn on time, $\tau_{on} = 50$ ns

Turn off time, $\tau_{off} = 200$ ns

Assume that the switch is in the ON state and OFF state for the same time duration at a switching frequency of 100 kHz and the reverse leakage current is negligible. By using the provided data, find the total power loss incurred by the MOSFET based on Figure 1.



$V_{GS} = 10$V

$V_{GS(th)} = 4$V

Figure 1

(20 marks)

Continued ...

QUESTION 4 [20 marks]

(a) A half wave diode rectifier has an AC input voltage of 250 V_{peak} with the output terminal connected to a 150 Ω load resistor.

Assume that the diode is ideal. Determine the:

(i) Average output voltage.

(2 marks)

(ii) RMS output voltage.

(2 marks)

(iii) Ripple voltage.

(2 marks)

(iv) Ripple voltage factor

(2 marks)

(v) State two disadvantages of half wave rectifier.

(2 marks)

(b) A converter is operating from a 5 V DC voltage source and it supplies 20 W across a 5 Ω load resistor under continuous conduction mode at the switching frequency of 10 Hz. Assume that the filter capacitance is very large. Neglect the ON state voltage drop across the diode. Compute for the following:

(i) The output voltage and duty ratio.

(4 marks)

(ii) The minimum inductance value needed for this converter.

(3 marks)

(iii) The output ripple voltage with a 20 mF capacitor.

(3 marks)

Continued ...

QUESTION 5 [20 marks]

(a) A single-phase half-bridge inverter has a DC input voltage of $V_s = 300\ V$. Determine:

(i) The RMS output voltage of the fundamental component.

(1 mark)

(ii) The RMS output voltage.

(1 mark)

(iii) The RMS output voltage of total harmonic component.

(2 marks)

(iv) The harmonic factor of the 1st, 2nd and 3rd harmonic.

(2 marks)

(v) The total harmonic distortion.

(2 marks)

(vi) The voltage transfer ratio.

(2 marks)

(b) A series resonant converter is operating at an output frequency of 8 kHz. The circuit turn off time is given as 45 μs.

(i) Sketch the circuit diagram of the series resonant converter. Label all the components clearly.

(4 marks)

(ii) Assume that the circuit turn off time is five times longer than the thyristor turn off time, determine the maximum permissible frequency, f_{max}.

Hint: $f_{\max} = \dfrac{1}{2(t_q + \dfrac{\pi}{\omega_r})}$

(6 marks)

End of Page.

APPENDIX

Table 1 Switching power loss of power BJT

	Resistive Load	Inductive Load
ON state	$P_{on} = [V_{CE(sat)} I_{C(on)} + V_{BE(on)} I_{B(on)}] \frac{t_{on}}{T}$	$P_{on} = [V_{CE(sat)} I_{C(on)} + V_{BE(on)} I_{B(on)}] \frac{t_{on}}{T}$
OFF state	$P_{off} = [V_{CC} I_{C(leak)}] \frac{t_{off}}{T}$	$P_{off} = [V_{CC} I_{C(leak)}] \frac{t_{off}}{T}$
Turn On	$P_{turn-on} = V_{CC} I_{C(on)} \frac{\tau_{on}}{6T}$	$P_{turn-on} = V_{CC} I_{C(on)} \frac{\tau_{on}}{2T}$
Turn Off	$P_{turn-off} = V_{CC} I_{C(on)} \frac{\tau_{off}}{6T}$	$P_{turn-off} = V_{CC} I_{C(on)} \frac{\tau_{off}}{2T}$

Table 2 Switching power loss of power MOSFET

	Resistive Load	Inductive Load
ON state	$P_{on} = I^2_{D(on)} R_{DS(on)} \frac{t_{on}}{T}$	$P_{on} = I^2_{D(on)} R_{DS(on)} \frac{t_{on}}{T}$
OFF state	$P_{off} = I_{D(off)} V_{DD} \frac{t_{off}}{T}$	$P_{off} = I_{D(off)} V_{DD} \frac{t_{off}}{T}$
Turn On	$P_{turn-on} = \frac{V_{DD} I_{D(on)} \tau_{on}}{6T}$	$P_{turn-on} = \frac{V_{DD} I_{D(on)} \tau_{on}}{2T}$
Turn Off	$P_{turn-off} = \frac{V_{DD} I_{D(on)} \tau_{off}}{6T}$	$P_{turn-off} = \frac{V_{DD} I_{D(on)} \tau_{off}}{2T}$

Table 3 Useful equations of DC to DC converters

Buck Converter	Boost Converter	Buck-Boost Converter
$V_o = DV_s$	$D = 1 - \frac{V_s}{V_o}$	$D = \frac{V_O}{V_s + V_O}$
$I_L = \frac{V_o}{R}$ $(\Delta i_L)_{close} = \frac{V_s - V_o}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$	$I_L = \frac{V_s}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_s}{L} DT$ $(\Delta i_L)_{open} = \frac{V_S - V_o}{L}(1-D)T$	$I_L = \frac{V_s D}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_S}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$
$L = \frac{(1-D)R}{2f}$	$L = \frac{D(1-D)^2 R}{2f}$	$L = \frac{(1-D)^2 R}{2f}$
$C_{\min} = \frac{1-D}{8Lf^2 \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$